Length-weight relationships of the Mimic shiner *Notropis volucellus* (Cope 1865) in the Western Basin of Lake Erie

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ABSTRACT. Gender relationships between total and standard length (mm) were compared to weight (mg) in the mimic shiner, *Notropis volucellus* for the western Lake Erie basin in the vicinity of the Bass Islands. Length and weight relationship (n=300), length-frequency distribution, and sex ratios (n=884) from a single date from Gibraltar Island in June 2012 were analyzed for coastal shoreline and tributaries. A strong positive correlation was found between length and weight for both males and females. In females, a significant positive correlation exists between standard length (SL) and body weight (F=671.5, d.f.=135) and between total length (TL) and body weight (F=681.4, d.f.=135). In males, there was also a strong positive correlation between SL and body weight (F=1744.9, d.f.=160) and between TL and body weight (F=1656.6, d.f.=160). Combining data for the two sexes helped determine a strong relationship between SL and body weight (F=1908.3, d.f.=299) and between TL and body weight (F=1885.9, d.f.=299) that was consistent with the results from the individual sexes. The growth patterns of male and female mimic shiner differed significantly for both SL (F=0.76, p>0.05, d.f.=159-134) and TL (F=0.76, p>0.05, d.f.=159-134). Age I females ranged from 29–51 mm TL and Age I males ranged from 30–46 mm TL based on 884 individuals from Gibraltar Island. Age II females ranged from 57–61 mm TL and Age II males ranged from 54–56 mm TL. Mimic shiner exhibit indeterminate growth and gender influences growth patterns.

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INTRODUCTION

Cyprinidae are the most abundant and diverse group of freshwater fishes in North America with over 200 species; however, other than taxonomic resolution, limited basic life history information exists for many species (Whittier and others 2000). In North American lakes and rivers, minnows are an important link in the aquatic trophic web (Stewart and Watkinson 2004), yet the difficulty in identification of these small species and their relatively little economic value have made minnows an under-studied group (Whittier and others 2000). Johnson (2009) indicated that minnows are becoming an important constituent of walleye diet in Lake Erie, in addition to clupeids and rainbow smelt. To better assess the ecological role of minnows in assimilation of lower trophic levels, a better understanding of the life history, growth, and age structure of these fishes is needed. Length-weight relationships are an important aspect of the life-history of a fish, as they can indicate a relationship between growth and maturity.

The mimic shiner, *Notropis volucellus* (Cope 1864) was first described in the Detroit River near Grosse Isle, Wayne Co., Michigan, in 1865 (Cope 1864). Mimic shiner are usually found in streams and rivers, but can also be found in lakes (Trautman 1982; Whittier and others 2000). Their indigenous range spans from the Atlantic Coast to the Great Lakes to the Gulf of Mexico, but in recent years they have been introduced to new waterways, such as the Connecticut River, as a result of human activities (Schmidt and Jacobs 2005). Mimic shiner are active insectivores found mostly in the benthic areas of the littoral zone (Olmstead and others 1979).

Greeley (1929) and Van Meter and Trautman (1970) reported the species as abundant and an important forage species around the islands in Lake Erie. Despite the former abundance of mimic shiner in the Lake Erie basin, recent estimates suggest that its abundance is declining (Ohio DNR 2012). This study investigated the relationship between length and weight in mimic shiner to better understand growth patterns based on gender as it pertains to their life history. In addition, the sex ratio and length frequency distribution was evaluated to predict age structure. Both length-weight relationships and age structure determinations are useful in comparing different populations and determining ecological impacts of this species. Lake Erie individuals collected from both coastal shoreline and tributary habitats within the western basin were studied to

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evaluate length and weight. The aim of the study was to determine whether mimic shiner exhibits indeterminate growth and specifically what correlation exists between two measures of length (i.e., total length [TL] and standard length [SL]) and weight based on gender. This information could be used to assess the health and feeding structure of different mimic shiner populations. The study also determined whether mimic shiner growth patterns are influenced by sex, and hypothesized that a difference in growth would occur between males and females. Differences in growth were assessed to find whether there was a significant difference between mimic shiner populations in the western basin associated with Lake Erie and its tributary rivers. Finally, the growth ranges and age structure of individuals from the Bass Islands were compared to other populations in the Great Lakes region.

MATERIALS AND METHODS

Study Area

Lake Erie is estimated to be less than 4,000 years old and is the fourth largest of the Great Lakes by surface area and the tenth largest lake globally (Munawar and others 1999). Lake Erie has a maximum length of 388 km, maximum width of 92 km, and a surface area of 25,744 km^2. The Western basin is the shallowest region of the lake with an average depth of 7.6–9.1 m (NOAA 2012). The Lake Erie islands are an archipelagic chain of islands in the Western Basin of Lake Erie comprised of 31 islands including Kelley Island, the Pelee Islands, and the Bass Islands (Ottawa Co, OH). Major tributaries that drain the coastal shoreline of Lake Erie in the vicinity of the Bass Islands include the Sandusky, Portage, Huron, and Vermilion rivers (Fig. 1).

Field Methods

Specimens used in the analysis were collected from coastal Lake Erie and tributary habitats (Fig. 1) using a variety of collection gear to reduce gear bias**.** Studies were conducted for a variety of purposes as part of investigations of the Bass Island region. Individual mimic shiner lots are part of the F.T. Stone Laboratory research collection on Gibraltar Island. Collection lots represent a variety of spatial and temporal scales (Murphy and Willis 1996). Specimens used in the current study were collected during ichthyological investigations of coastal shoreline and tributary research during the middle of the spawning season (June-July 2010-2012) (see Supplemental Materials: Specimens Examined Section). Length and weight relationships were based on 300 individuals from coastal shoreline and tributaries in the Western Basin of Lake Erie, while

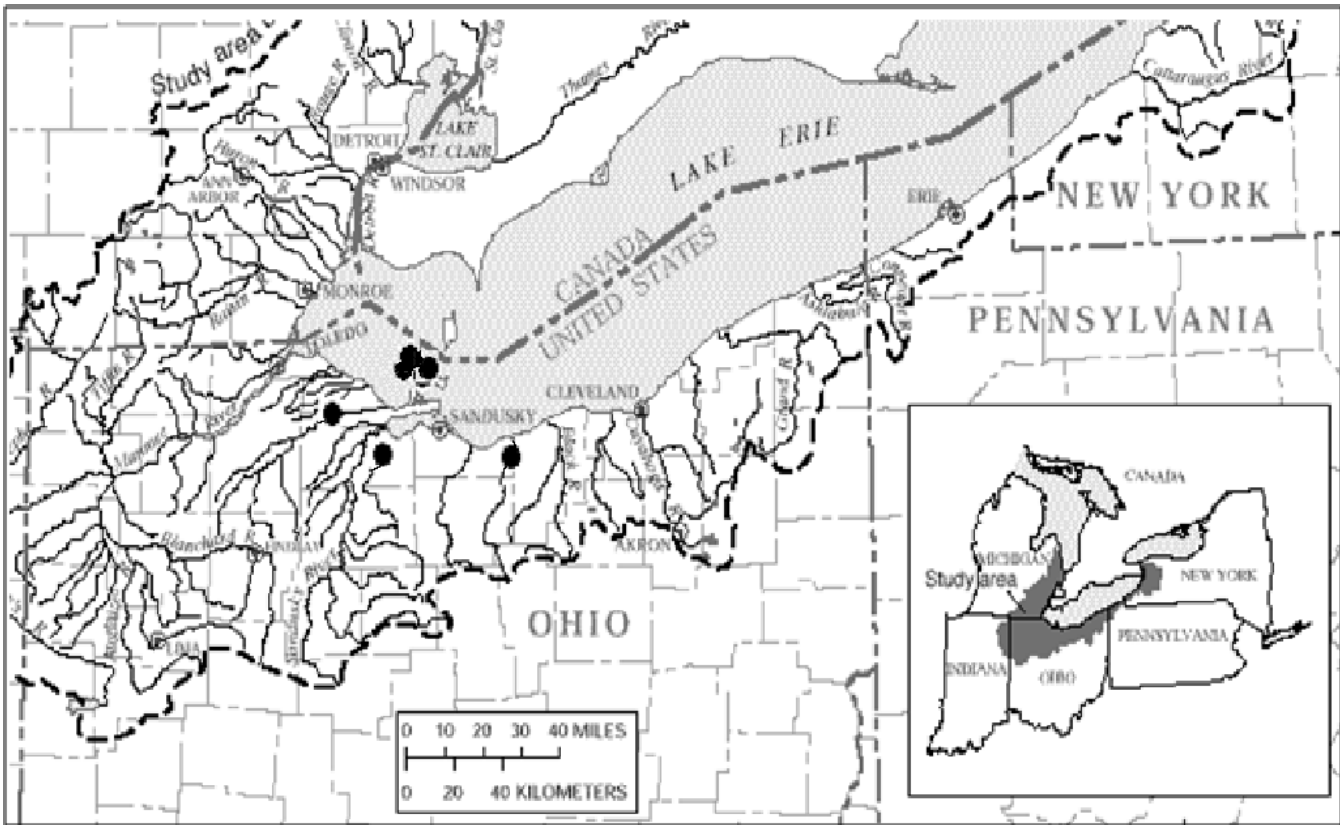

FIGURE 1. Lake Erie basin showing the Western Basin and primary tributaries and locations sampled within the study area.

length-frequency distribution and sex ratios were based on a single collection of 884 individuals from a single date from Gibraltar Island in June 2012. Lot collections are maintained as part of the permanent collection of the Museum of Biodiversity, The Ohio State University, Columbus.

Laboratory Methods

Individual fish were removed from site-specific collection lots and each was blotted dry to remove excess moisture prior to wet weighing using a Sartorius balance with a resolution of 1 μg. Due to the precision of the balance used in the analysis it would be impractical to measure live individuals or to attempt to weigh fish in the field. Fish were anesthetized in MS222 and fixed in 10% formalin. The fish used in the laboratory analysis were soaked in water just prior to being measured. The relationship between weights of freshly preserved individuals was tested to verify that weights were accurate. No substantial shrinkage in specimens were found and the study observed less than 2% changes in weight within the time frame of the measurement of individuals; however, it is recognized that the data might not completely reflect the length-weight relationships of live individuals. The overall relationship between length and weight was assumed that it would be equally affected because all specimens were preserved in the same manner. Each individual was examined using a Leica stereozoom dissecting microscope to determine sex. Males possessed pointed pelvic fins that often covered the genitals. A bifurcate gonopod was observed in males, while female cloaca possessed a short ovipositor that contained a slightly enlarged tube for egg deposition. Two measurements of length, standard length (SL) and total length (TL), were determined to the nearest mm. Methods for measuring the lengths and weights of the specimens followed standard methods (Hubbs and Lagler 2004). The SL was measured along the horizontal body axis from the tip of the snout to the posterior end of the notochord at the hypural plate, while TL was measured along the horizontal axis from the tip of the snout to the tip of the depressed caudal fin. Age groups of the specimens were determined by length frequency distribution analysis (Nielson and Johnson 1983).

Statistics

Simple regression was performed to determine if a significant relationship was observed between length and weight. The length measure and weight were graphed using a best fit trend line and the results were evaluated using simple regression. To assess the role of sex in the growth of the mimic shiner, an Analysis of Covariance (ANCOVA) (STATISTICA 11.0) was performed to compare body weight and length, i.e., SL and TL, between males and females. To assess whether habitat class affected the size of the mimic shiner, individuals were separated into lake and tributary river population groups and an ANCOVA was used to compare body weight and length (SL and TL) for males and females. To assess whether there was a significant difference in the size distributions over age classes between males and females, an ANOVA was used to compare length frequencies from the specimens collected at Gibraltar.

RESULTS

The study analyzed mimic shiner from the Western basin of Lake Erie, the East Branch Huron River, and from Wolf Creek to determine length weight relationships (n=300) and individuals from Gibraltar Island (n =884) for sex ratio and age and growth. Female mimic shiner showed a significant positive correlation between SL and body weight (R^2=0.909, F=671.5, d.f.=135; Fig. 2a) and between TL and body weight (R^2=0.912, F=681.4, d.f.=135; Fig. 3a). In male mimic shiner, there was a strong positive correlation between SL and body weight (R^2=0.909, F=1744.9, d.f.=160; Fig. 2b) and between TL and body weight (R^2=0.912, F=1656.6, d.f.=160; Fig. 3b). The trend line between both measures of length with weight in males and females was best explained using a polynomial curve.

Growth patterns in the mimic shiner were significantly influenced by gender (ANCOVA, F=8.31, p>0.01). There was a significant difference in both SL (ANCOVA, F=5.97, p=0.01) and TL (ANCOVA, F=5.63, p=0.01) between males and females. No significant difference was observed in the adjusted body weight between males and females (ANCOVA, F=1.04, p=0.31,). Combining data for the two sexes, a polynomial relationship was observed between SL and body weight (R^2=0.909, F=1908.3, d.f.=299; Fig. 2c) and between TL and body weight (R^2=0.912, F=1885.9, d.f.=299; Fig. 3c) that was consistent with the results from each individual gender.

Variation in length and weight was observed between mimic shiner collected from Lake Erie and those collected from its tributary rivers. In male mimic shiner, significant difference were found in body weight (ANCOVA, F=30.102, p<0.01) and TL (F=2.607, p<0.01; Fig. 4c) between the lake and river populations, but there was no significant difference in SL (ANCOVA, F=0.838, p=0.36; Fig. 4a). In female

mimic shiner, significant differences were found in both SL (ANCOVA, F=5.965, p=0.01; Fig. 4b) and TL (ANCOVA, F=5.634, p=0.01; Fig. 4d) between the lake and river populations. There was no significant difference in body weight for females between the two populations (ANCOVA, F=1.047, p=0.307).

A skewed sex ratio resulted from a sample of 884 individuals collected from the beach along the dock at Gibraltar Island at the F.T. Stone Laboratory. Males outnumbered females 1:0.608.

Length frequency distribution of male and female individuals from Gibraltar Island (n=884) is shown in Fig. 5. No significant difference in size was exhibited between male and females (ANOVA, F=1.16126, d.f.=333,549, Fig. 5). Based on the size and age distributions of the fish collected, it was hypothesized that the mimic shiner were in the act of spawning along a shallow (0.5 m depth) cobble beach of Gibraltar Island. As a result, age- 0 recruitment class was not yet of catchable size to be reflected in our gear. Two age classes are shown with Age I females ranged from 29–51 mm TL and Age I males ranged from 30–46 mm TL. Age II females ranged from 57–61 mm TL and Age II males ranged from 54–56 mm TL.

DISCUSSION

Carlander's (1969) extensive review of age and growth relationship studies did not reveal that any length-weight studies had previously been published for the mimic shiner. Relationships between size and age,

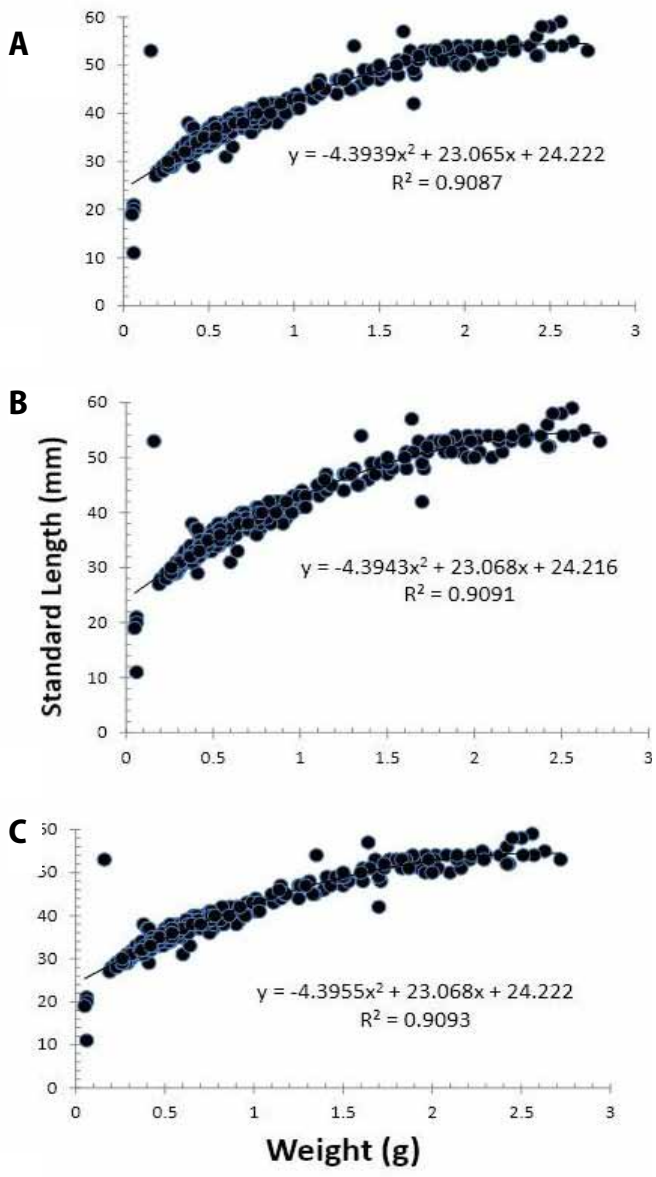

FIGURE 2. Relationship between standard length (mm SL) and adjusted body weight (g) for Mimic shiner *Notropis volucellus*. (a) male, (b) female, and (c) both sexes in the Western Basin of Lake Erie.

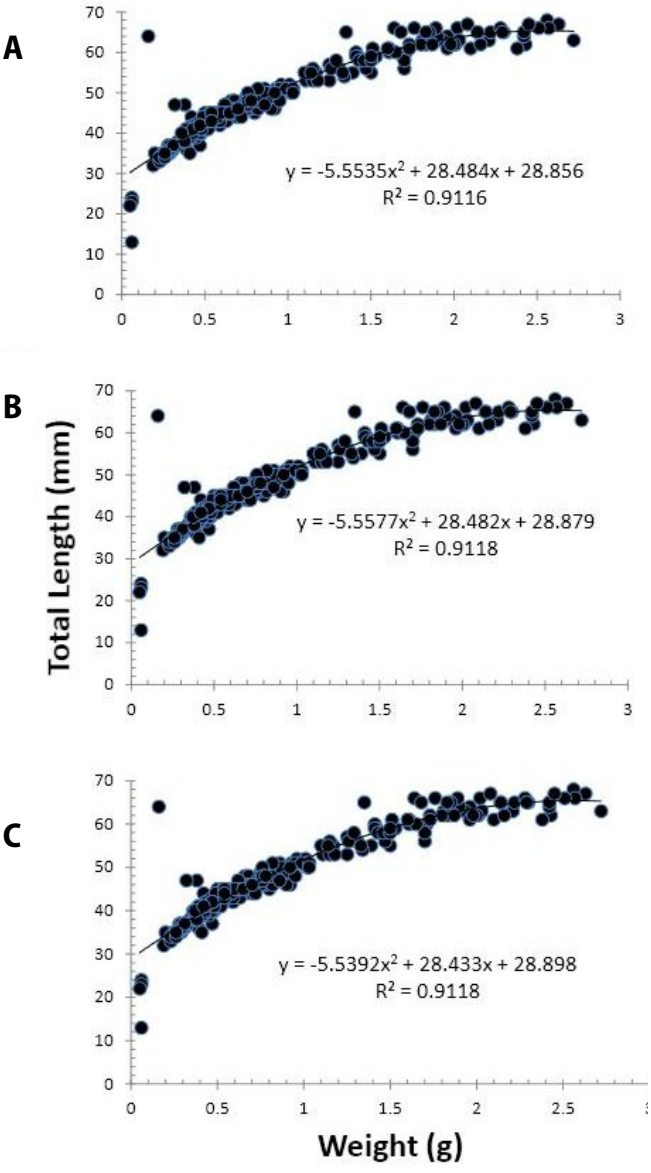

FIGURE 3. Relationship between total length (mm TL) and adjusted body weight (g) for Mimic shiner *Notropis volucellus* for (a) male, (b) female, and (c) both sexes, in the Western Basin of Lake Erie.

i.e., comparing age (in years) to total length, have been conducted in the Great Lakes (Table 1; Black 1945; Becker 1945; Trautman 1982). This comparison provides an estimate of age based on TL. Although a latitudinal gradient was expected within the Great Lakes region, i.e., northern latitudes of Wisconsin to southern latitudes of Ohio, the study found that southern populations attained a larger size at age than northern populations. In addition, these studies show a positive relationship between age and weight.

A strong relationship between estimated age using length frequency distribution was observed among Lake Erie populations from Gibraltar Island with other reported studies based on body weight and both

Table 1
Mimic shiner age and growth relationships based on literature from the Great Lakes region

Location	TL Range (mm) Age 0	Age I	Age II	Study
Ohio	20-40	30-64	38-76 (adult)	Trautman (1982)
Indiana	--	50.2-62.8	69.0-71.5	Black (1945)
Wisconsin (Black River)	--	43-52	52-65	Becker (1945)
Ohio (LakeErie)	--	29-51 female 30-46 male	57-61 female 54-56 male	Current study

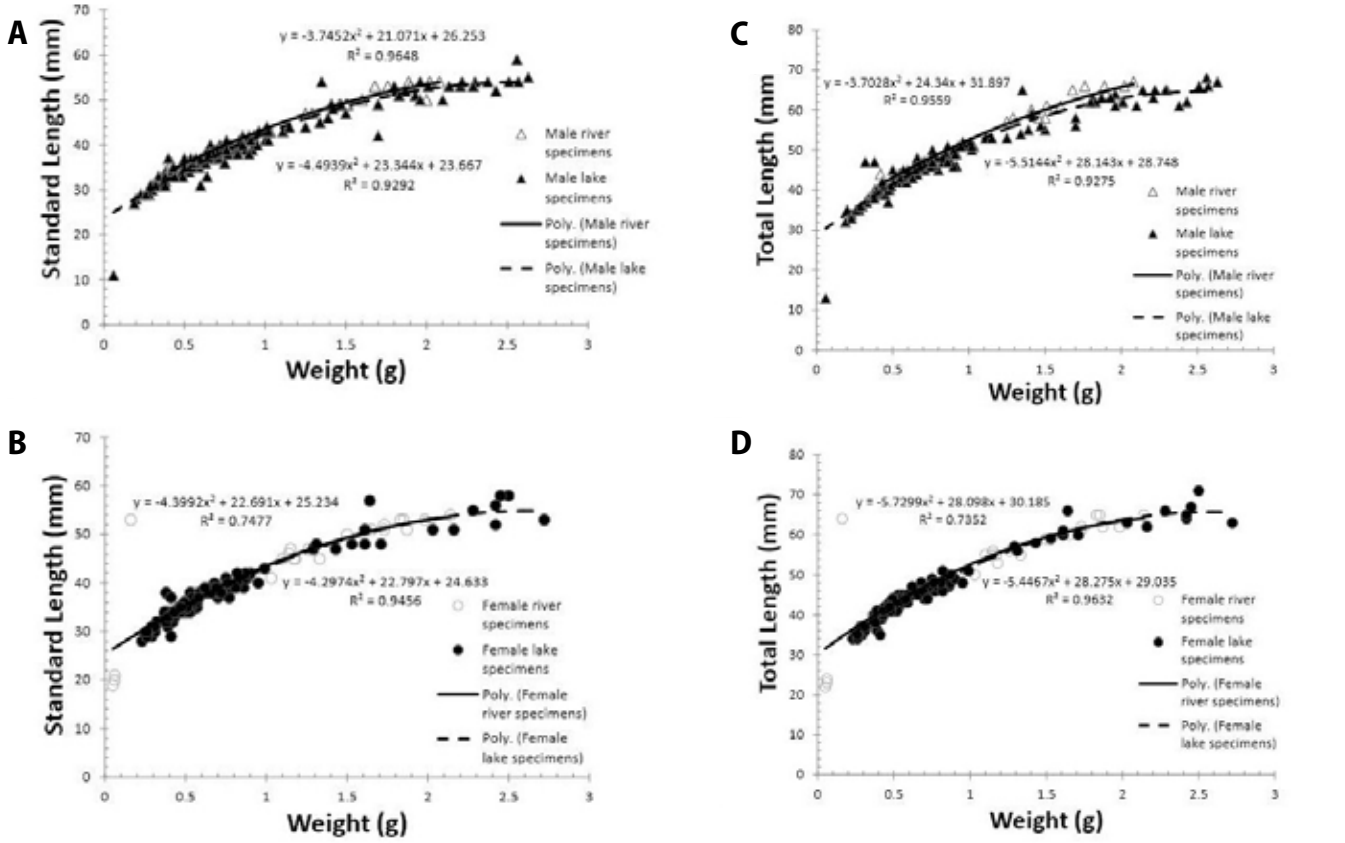

FIGURE 4. Comparison of the length-weight relationships between the lake and river populations with standard length (mm SL) and adjusted body weight (g) for (a) males and (b) females and total length (mm TL) and adjusted body weight (g) for (c) males and (d) females.

SL and TL in both genders of the mimic shiner. Lake Erie populations live to Age II and exhibited similar growth relationships as reported by Trautman (1982) and Becker's (1983) reported size at age; however, this study's data is based on individuals collected in June, while Trautman and Becker's data were from October. Only Black's (1945) study from an inland Indiana lake exhibited greater growth at age compared to this study.

Significant differences in the length and weight relationships were observed between males and females indicating that mimic shiner have a growth pattern that is influenced by sex. Based on the positive relationship between length and weight, it can be infered that mimic shiner exhibit indeterminate growth. In the samples, fish were represented in each of the reported age categories, and because the results show a strong positive correlation between length and weight, it can also be inferred that there is also a strong positive relationship between age and length and age and weight.

No significant differences were expected in growth between populations in Lake Erie and in tributary rivers since populations are not isolated from each other and can migrate freely. The study instead found a significant difference in growth between the populations for both males and females. The significant difference in growth for females between the populations may be correlated to the spawning season. All of the specimens were collected during the spawning season, which could account for larger females being found in the Lake Erie population. The significant difference in growth between populations for both males and females may also be skewed by the small sample size of mimic shiner from the tributary rivers.

Future studies are needed to determine whether the length-weight relationships we found in the western basin of Lake Erie and its tributary rivers are consistent with other regional basins. This study emphasizes the importance of studying applied ecological relationships among other members of the family Cyprinidae. Cyprinids may be important either by directly shaping populations of other game fish by competing for resources or indirectly by diversifying the forage base (Schmidt and Jacobs 2005). Thus, if for any reason cyprinid populations begin to change, i.e., due to nutrient stimulation, climate change, or Great Lake water level fluctuations, other recreationally and commercially important species could be affected.

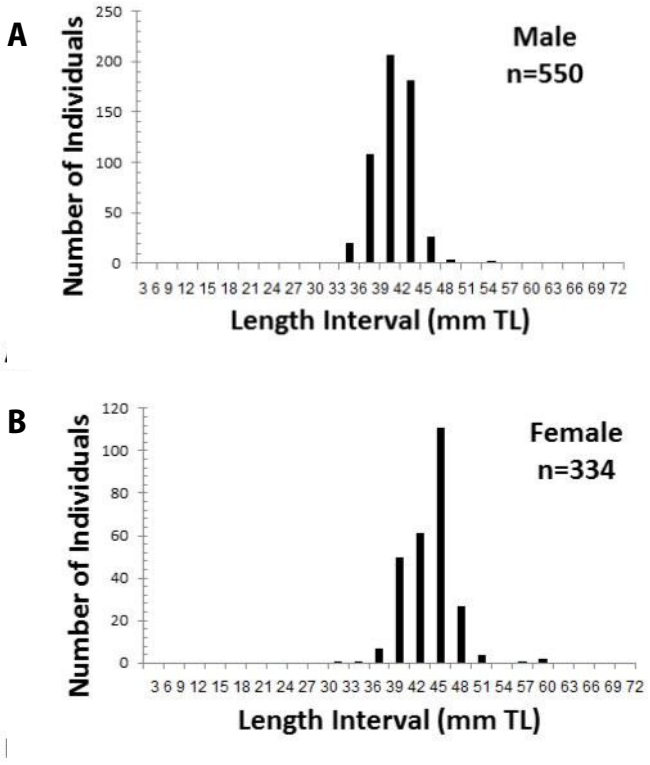

FIGURE 5. Length frequency distribution of Mimic shiner from Gibraltar Island, Western Lake Erie basin (41.65822N, -82.82151W), 23 June 2012, from the F.T. Stone Laboratory cobble beach.

ACKNOWLEDGEMENTS

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SUPPLEMENTAL MATERIALS

Specimens Examined

OHIO: *Erie Co*. Wolf Creek u/s OH SR 53 Bridge 3.5 mi S Fremont, Baltville Twp., 41.28090N -82.16991W, VII:7:2011, TP Simon & EEOB 621, (N=6);

Erie/Lorain Co. East Branch Vermilion River u/s Green Road Bridge 8.5 mi S Vermilion, Florence Twp., 41.30227N -82.343181W, VI:29:2011, TP Simon & EEOB 621, (N=3).. East Branch Vermilion River u/s Green Road Bridge 8.5 mi S Vermilion, Florence Twp., 41.30227N -82.343181W, VI:30:2010, TP Simon & EEOB 621, (N=2);

Huron/Erie Co. Huron River Lovers Lane Bridge 3 mi. NW Norwalk, Norwalk Twp., 41.28667N -82.64260W, VI:30:2010, TP Simon & EEOB 621, (N=6); Huron River Lovers Lane Bridge 3 mi. NW Norwalk, Norwalk Twp., 41.28667N -82.64260W, VI:29:2011, TP Simon & EEOB 621, (N=31).

Ottawa Co. Lake Erie East North Bass Island, North Bass Island, North Bass Island Twp., 41.28090N -82.16991W, VIII:5:2004, EEOB 621, (N=83); *Ottawa Co*. Lake Erie, Gibraltar Island, Bathing Beach, Put-in-Bay, SE Gibralter Island, South Bass Island Twp., 41.65822N -82.82151W, VI:24:2011, TP Simon & EEOB 621, (N=106); *Ottawa Co.* Lake Erie, Gibraltar Island, Dock Beach, Put-in-Bay, SW Gibraltar Island, South Bass Island Twp., 41.65775N -82.82164W, VI:24:2011, TP Simon & EEOB 621, (N=7); *Ottawa Co*. Lake Erie, Gibraltar Island, Alligator Bar, Put-in-Bay, SW Gibraltar Island, South Bass Island Twp., 41.6574N -82.82291W, VI:24:2011, TP Simon & EEOB 621, (N=22); *Ottawa Co*. Lake Erie, Gibraltar Island, Bathing Beach, Put-in-Bay, SW Gibraltar Island, South Bass Island Twp., 41.656975N -82.822852W, VI:23:2010, TP Simon & EEOB 621, (N=7); *Ottawa Co.* Lake Erie, Green Island track, 1.3 km off Green Island, 41.37.799N -82.51.769W (B) 41.37.366N -82.51.813W (E), VI:27:2011, TP Simon & EEOB 621, (N=1); *Ottawa Co.* Lake Erie, Middle Bass Island gravel beach off North Pointe, Middle Bass Island Twp., 41.69283N -82.80120W, VI:30:2010, TP Simon & EEOB 621, (N=33). *Ottawa Co.* Lake Erie, dock beach, Gibraltar Island, adjacent F.T. Stone Laboratory, 41.65775N -82.82164W, VI:23:2012, TP Simon & EEOB 5930, (N=884).